

The Effect of H₂O on the Anomalous Elasticity of Rhyolitic Glasses and Implications for Crustal Melt Detection

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Rhyolitic eruptions can be some of the largest and most devastating. Corresponding melts are prevalent in Earth's crust and can contain significant amounts of water up to 10 wt.%. Detection and identification of such melts remains challenging for geophysical methods due to the lack of experimental data at relevant P-T conditions. Acoustic velocities and elastic moduli of dry and hydrous rhyolitic glasses containing up to 5.90 wt.% H₂O_t have been determined up to 3 GPa at ambient temperature in a diamond anvil cell using Brillouin Light Scattering. FTIR spectroscopy was used to measure the speciation of water in the glasses as a function of pressure. These results indicate that molecular water (H₂O_m) is converted into hydroxyl groups (OH) as pressure is increased. This conversion mostly occurs at pressures below ~1.5 GPa and is more pervasive in glasses with higher water contents. At low pressures, the addition of water decreases both acoustic velocities and elastic moduli. This is due to the depolymerization of the silicate network as water is incorporated as OH. As pressure is increased acoustic velocities decrease with increasing pressure up to ~1-2 GPa before increasing with pressure. This anomalous pressure dependence is associated with the collapse of interstitial void spaces and the tightening of bond angles between bridging tetrahedra. The transition pressure at which velocities transition from decreasing with pressure to increasing with pressure is different between the dry and hydrous glasses and is found to be closely related to the polymerization of the glass. Above ~1-2 GPa, both V_p and bulk moduli in the hydrous glasses become higher than V_p and bulk moduli in the dry glass. This stiffening is attributed to the presence of H₂O_m in interstitial sites, which prevents the compression of the surrounding silicate network. From our measurements, we modeled the velocities of rhyolitic glasses containing up to 5.90 wt.% H₂O_t at ambient temperatures. Considering potential high-temperature effects, our results allow constraints to be placed on melt compositions and volatile contents in natural rhyolite melts at shallow depths. Furthermore, we discuss how the crossovers in velocities may be manifested in hydrous melts in Earth's interior.